Ultra-Fast-Triggered Semiconductor Devices for Enhanced System Resiliency

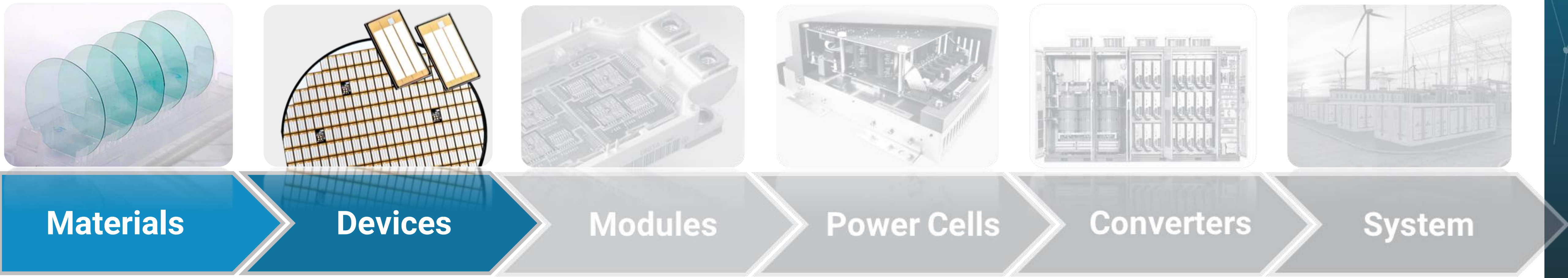
New Program Development Workshop

Day 1 Breakout Sessions

- Materials/Devices
- Modules/Power Cells

Materials/Devices

CHANGING WHAT'S POSSIBLE



Day 1 Discussion

What are the gaps in grid-level power electronics and their control today and in the future, that cannot be addressed with existing semiconductor device technology?

CHANGING WHAT'S POSSIBLE

Are given performance metrics aggressive, yet achievable, for single devices?

- How can optical excitation help achieve/improve these metrics?
- Which ones are most/least challenging?
- Can they be achieved simultaneously or are tradeoffs necessary?
- How to best capture reliability metrics given low TRL of potential solutions?

Category	Target
Rated Device Voltage	≥ 10 kV
Device Current	≥ 100 A
Switching frequency	≥ 200 kHz
Switching loss reduction	30% of SOTA
Turn-On/Off time	< 0.1 µs
Turn-On delay	< 3 ns

CHANGING WHAT'S POSSIBLE

What are challenges and possible mitigations associated with potential material choices?

- Material maturity, substrate availability, conductivity control, thermal properties, carrier mobility, etc.?
- How does optical (or other) excitation impact the material choice?

CHANGING WHAT'S POSSIBLE

Innovative device options

- What novel device concepts could be realized and why?
- What legacy device technology could be improved, how and why (SCR = Silicon-Controlled Rectifier, GTO – Gate Turn-off Thyristor, LTT – Light Triggered Thyristor, IGCT - Integrated gate-commutated thyristor, IGBT - Insulated-Gate Bipolar Transistor, etc.)?
- What leveraging opportunities are there from adjacent fields such as vacuum electronics, RF/microwave devices and photonic devices for datacom and telecom?
- What are opportunities for self-protecting device designs (at a die-level)?

What are opportunities and challenges associated with realization of PCSS (Photo conductive semiconductor switch) devices?

- What are most promising materials and why?
- What are optical triggering requirements (wavelength, power, temporal properties) and what are optical source/system options?
- What role could these types of devices play (linear and non-linear) in supporting novel concepts for grid control and protection?

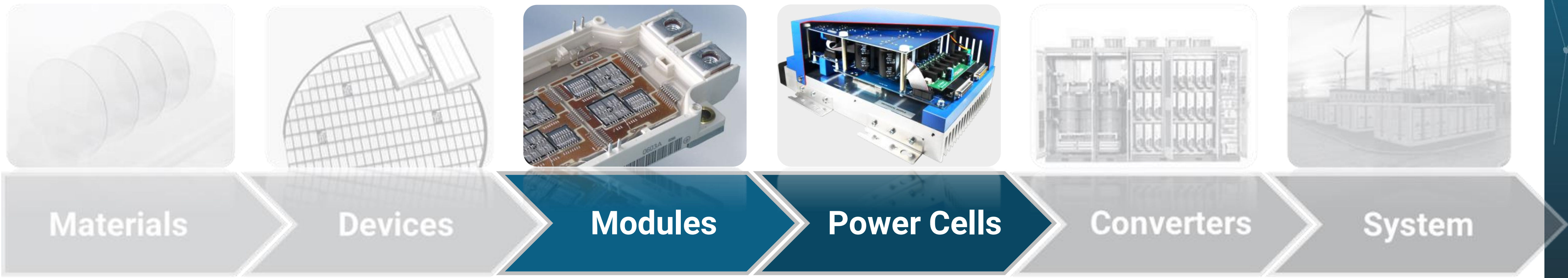
What other material/device innovations (besides switching devices) are needed to support operation at higher power and higher dv/dt (and di/dt) and address EMI suppression?

- What are possible packaging strategies to address thermal, optical, EMI, E- field management, reliability, etc. requirements?
- Should monolithic integration be targeted and to what extent (i.e., UWBG device, optical control device and its drive electronics, thermal management in one package)? What performance metric could capture the tradeoffs involved in this decision?
- What innovation is needed for passive components (inductive and capacitive)?

Question 7/7 [5 mins]

What other opportunities/challenges/issues at material/device level should we consider?

Modules/Power Cells



Day 1 Discussion

CHANGING WHAT'S POSSIBLE

What are the gaps in grid-level power electronics and their control today and in the future, that cannot be addressed with existing semiconductor device technology?

CHANGING WHAT'S POSSIBLE

Are given performance metrics aggressive, yet achievable, for power modules?

- How different should module metrics be from those of a single device?
- Which ones can/should be traded against each other (achieved simultaneously)?
- Which ones are most/least challenging?
- How to best capture reliability metrics given low TRL of potential solutions?

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1) What are potential benefits and challenges of optical control?

- What would be enabled with new (optical and others) approaches?
  - EMI immunity?
  - Better/easier device stacking?
  - Improvement in efficiency, switching losses?
  - Safety improvements (hot-swappability)?

- EMI mitigation: How to measure improvement? What are the right metrics? Does compliance with applicable standards and regulations ensure a sufficient level of EMI immunity, or are better/different metrics and assessments needed? If they are not, why, and what are the better ones?

- At what level should the optical components be integrated? Should integrated microsystem performance be targeted (i.e., UWBG device, optical control device and its drive electronics, thermal management, etc., in one package)? What performance metric could capture the tradeoffs involved in this decision?

CHANGING WHAT'S POSSIBLE

Innovative power module/power cell structures

- What novel structures can be realized utilizing light or other means for fast triggering?
- Which novel techniques can be enabled for paralleling and cascading dies/modules in one package using active (i.e. optical) dv/dt and di/dt control for die-level voltage balancing and equal current sharing?
- What opportunities are there for active die- and module- level bypass and protection?
- What improvements are possible for novel power cells utilizing modules featuring triggering unconstrained by wire?

Strategies for packaging for such novel power modules/power cells structures – thermal, optical, EMI issue, E- field management along with potential impact on reliability?

- Co-design of device/package/module/… optimizing optical, temporal, EMI, HV breakdown and thermal properties – models and novel manufacturing methods?
- Potential component material choices (insulating materials, common substrates, encapsulants, wire-bonds, interposers, heat spreaders, power connectors, enclosures, etc.)?

What other supporting innovation is needed?

- Power cell-integrated (or even power-module integrated) passives to support more capable (higher power, faster, more robust, etc.) power modules/cells for modular converters?
- Light sources needed: Lasers vs. LEDs? Optical distribution system? What about drive electronics for these sources? Where to put them in the system to best mitigate EMI (best level of integration)?
- Other capabilities like bidirectionality, surge protection (Metal Oxide Varistors), or functional replacements?
- Sensing? Do sufficient sensing capabilities exist to support this vision? If not, what is missing?

What other opportunities/challenges/issues at power modules/power cells - level should we consider?